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Battelle
Putting Technology To Work

Probable Levels of R&D Expenditures in 1989

Forecast and Analysis

This Battelle report is based upon a continuing study of U.S. expenditures for research and development. It was prepared by Drs. Jules J. Duga and W. Halder Fisher of Battelle's Columbus Division. Parts of the data presented here were derived from such sources as the National Science Foundation, the McGraw-Hill surveys, and others.

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PROBABLE LEVELS OF R&D EXPENDITURES IN 1989
SUMMARY OF FINDINGS

1. Battelle forecasts that the total U.S. expenditures for R&D will be $129.2 billion during calendar year 1989. This is an increase of 3.4 percent over the $124.9 billion that the National Science Foundation (NSF) estimates actually will have been spent in 1988.

2. Costs of performing R&D are expected to rise approximately 1.2 percent from 1988 to a 1989 index level of 135.95 (1982 = 100 percent), absorbing a portion of the increased funding. However, this implies a *real* increase in expenditures of approximately 2.23 percent, reaching a new peak in total real funding of R&D (Figure 3).

3. Federal government funding in 1989 is expected to be about $60.3 billion (46.7 percent of total), an increase of $1.13 billion (1.9 percent) from 1988. Performance of R&D by the federal government will represent $14.7 billion (11.4 percent), an increase of $171 million (1.2 percent) over 1988 estimates.

4. Industrial funding in 1989 is expected to be $63.3 billion (49.0 percent of total) representing an increase of $2.8 billion (4.6 percent) over that of 1988. Performance of R&D by industry is expected to rise to nearly $92.7 billion (71.7 percent of total), an increase of $3.3 billion (3.7 percent over 1988).

5. Estimates of federal government versus industry support for the R&D performed by each of several broad industrial sectors are included in the 1989 forecast. Drawing upon historic trends, the anticipated total performance by the industrial sector has been calculated; first within each of 17 major industrial groups, and then according to whether that performance is supported by federal government or industrial funds. These estimates are shown in Table 4.

6. In 1989, the federal government is expected to support slightly over four-fifths of the aerospace industry's R&D activity, approximately two-fifths of electrical machinery/communications, and more than one-fourth of the R&D in the primary metals industries. All other broad manufacturing industry classes are expected to be supported primarily by industry funds with these ratios ranging from 83 percent for the ground transportation industries up to 100 percent for the food and beverage, pulp and paper, and textiles industries. Overall, 33 percent of industrial R&D will be federally funded with the remainder funded by industry.

7. Academic and other nonprofit institutions taken together are expected to fund nearly $5.6 billion of R&D in 1989 (4.3 percent of total) and to perform over $21.8 billion (about 17 percent). These figures represent almost negligible increases in the percentage of support and performance over the 1988 NSF estimates. These figures also include the federal support to Federally Funded Research and Development Centers which are managed by individual universities or consortia.

8. Within the nonprofit category, colleges and universities are expected to account for 67.5 percent of the 1989 funding and 83.3 percent of the R&D performance. Both of these figures are comparable with the ratios derived from the 1988 NSF estimates.

9. Historically, the costs of R&D performance have risen steadily in all four categories (federal, industrial, colleges and universities, and other nonprofits), with the rate of increase being driven by overall inflation, and so-called "sophistication" factor.

10. The trends in real R&D effort (see Figure 3) continue to move upward, as they have over much of the past decade. Since 1977 real R&D effort has increased at a 10-year average rate of 3.6 percent, and the projections for 1989 suggest that the 11-year average rate will be slightly smaller (3.3 percent). Battelle estimates that during the next few years real R&D activity will increase at an average annual rate of approximately 2.8 percent, *slightly lower than recent behavior, but maintaining a generally upward trend.*

11. Significant factors that appear to be influencing trends in the support and performance of R&D include:

    (a) Federal government emphasis on defense programs will have a continued influence on total R&D support and the principal industrial performers. These emphases will be felt primarily in the aerospace, electronics, and communications industries, but the rate of growth is expected to show a continued decline and a possible turnaround under the new Administration.

    (b) Energy-related R&D programs will continue to experience mixed federal support, with increased funding in basic energy sciences and defense-related energy programs. In addition, health-related R&D will receive a significant boost over previous levels of funding.

(c) Uncertainties related to the stock market and the continuing debate on tax laws will have a small effect on industrial support of R&D. Greater impacts may be felt as a result of industrial restructuring, a renewed emphasis on short-term profits, and the decline of the dollar.

(d) University self-funding of R&D is expected to continue to show real increases, partially as a result of industrial "directed programmatic endowment" support of basic and applied research, and a continued support of cooperative research programs.

(e) The Gramm-Rudman-Hollings Act has not affected the rate of growth of government-funded R&D to the extent anticipated. However, other federal actions and the new Administration will influence both federal and industrial support.

12. As a continuing feature, this report provides a preliminary forecast of R&D funding levels in 1990. Indications are that total U.S. expenditures for R&D in 1990 will be $133.3 billion (uncorrected for inflation).

13. The types of statistics and surveys which are readily and publicly available are shown to be sufficient for broad analyses of U.S. R&D trends; however, it is shown that much more detailed work will be required if R&D analyses are to be more useful for defining competitive postures, both for individual industries and for the nation as a whole.

ANALYSIS AND FORECAST

Since research and development (R&D)* and the applications of technology are our prime concerns, Battelle is interested both in forecasting R&D expenditures and in assessing the cumulative results of R&D activities—technological, economic, and social. Accordingly, Battelle has carried on a continuing study into the forces affecting R&D activities and sources of support. Among the tangible products of this research has been a series of annual analyses and forecasts of R&D expenditures. This report represents the latest in that series.

The content of this report has evolved over the years in an attempt to supply information Battelle considers useful to the R&D community, but not adequately supplied by two well-known and respected series of reports: the National Science Foundation's *National Patterns of Science and Technology Resources* and the DRI/McGraw-Hill *Annual Survey of Business Plans for R&D.*

*The National Science Foundation's definitions of R&D are given in the Technical Appendix to this report.

In earlier years, NSF *Patterns* was published during the first half of each year (usually in April) and had included a forecast of that same full year's R&D expenditures by source of funds and by performer. However, since the fiscal year now begins in October, *Patterns* had contained both the preliminary data for the closing fiscal year and estimates for the two preceding years. Recently, the publication of *Patterns* has been delayed until late in the calendar year, and it contains better estimates of the R&D funding and performance for that same year. In addition, selected *Highlights* reports have made preliminary estimates of the forthcoming year's R&D activities (in this case, an estimate for 1989).

Budget restraints at NSF have taken their toll on the *Patterns* report and the supporting activities throughout the NSF Division of Science Resource Studies. The effects of these cutbacks have been felt not only by continuing private-sector users of NSF data but also by policy makers and analysts within the federal government. As an additional complication, NSF data have always had a degree of uncertainty, especially as they relate to recent years' histories. Each year, the NSF data on previous years (sometimes as far back as 10 years) have been subject to corrections. For example, the 1984 data reported in 1988 are different from the 1984 data that were published in 1987. These adjustments thus present problems in consistency between forecasts made in different years. The lack of background data and their interpretation can only have a negative impact on those agencies concerned with the strength of the U.S. R&D effort and the policy measures that need to be taken in order to assure competitive postures. More will be said of this in later sections of this Forecast.

The McGraw-Hill surveys (usually published at about the same time as the earlier issues of *Patterns*) make forecasts—the 1988 Survey (published in June) made forecasts for 1988 and 1990—but are confined to the overall performance of broad industrial sectors, some of which are not well defined and delineated, and do not separate federal government from industrial funding. These surveys, coupled with the "R&D Scoreboard" published in midyear by *Business Week*, are instructive to the extent that they provide generalized patterns and trends. However, as will also be shown in later discussions (see the Section titled "The Need for Better Data"), they fall far short of providing a useful tool for detailed analysis, evaluation, or planning.

The Battelle report, usually published in December or shortly after the beginning of the subject year, has been intended to fill the remaining void, by emphasizing the coming year (in this case, 1989) and industrially funded R&D. Other relevant inputs, gleaned from many sources, have also been included. While this present Forecast addresses some gaps in information, it also shares some of the shortcomings of other related documents.

Since the issuance of the 1980 Forecast, we have included a forecast of industrial R&D expenditures according to broad industry class, along with the estimated distribution of those funds between industrial and federal sources. This added feature provides the background necessary for understanding the way federal policy can affect industrial innovation, spur industrial support of its own R&D efforts, and enhance the long-term international competitiveness of U.S. industry. Although related aspects of productivity, training and manpower needs, tax incentives, balance of payments, and other concerns are not predictable, we anticipate that continued analysis of this subject—as well as detailed studies of line-of-business or line-of-activity R&D—will help identify both the promises and the problems associated with industrial responses to future opportunities.

Continuing the practice initiated in the 1984 Forecast, we present estimates which cover a two-year forecast to 1990.

Historical Trends in R&D Funding and Performance

Although the NSF data series began in 1953, we begin our analysis with 1960 data. Even that year represents ancient history so far as the forces currently affecting R&D are concerned. The NSF data from 1960 through 1988 are shown in Table 1.

In 1960, NSF surveys indicated that approximately 64.6 percent of all R&D-supportive funds were provided by the federal government; 33.4 percent were provided by industry; and 1 percent each came from the academic community and from other nonprofit organizations.

Between then and 1984, federal funding rose to 66.5 percent in 1964, slowly declined to 46.0 percent in 1982, and has risen slowly since that time.* Over that same period, industrial funding declined to 31.2 percent in 1964 and rose to 50.2 percent in 1982, with a small decline thereafter. Since 1964, the two nonprofit sectors have risen gradually, colleges and universities to almost 2.3 percent of total R&D funding, and other nonprofits to almost 1.6 percent. However, over the past decade, nonprofit support has declined steadily, while college and university support has blossomed in the last five years. This latter growth is partially ascribable to the more detailed bookkeeping methods that are used to account for this sector's sources of funds.

*Note that NSF data for 1987 and 1988 are "estimated." However, comparisons among the series of *Patterns* reports reveal that adjustments are made on earlier years' figures, with some adjustments carrying back several years. Thus, many of our calculations that are dependent upon long-term figures will vary from one year to the next.

Through 1982, trends showed a continued increase in industrial funding as a percent of total funding, with a corresponding decrease in the proportion of federal-sector funding. Over the past four years, however, the relative contributions by industry and the federal government have remained essentially constant. This is largely due to significant increases in defense spending, industrial response to a healthier economy, and other initiatives (see the later discussions on the role of industry).

Although the federal government had been the major *source* of R&D funds from 1953 to 1979, industry became the dominant R&D funder over the period 1980–1988, with the exception of 1986. Industry is by far the major *performer* of R&D. Federal performance of R&D rose from 12.8 percent in 1960 to 16.1 percent in 1972. It has been decreasing since that year and has fluctuated around the 12 percent mark since 1980. Industrial performance reached a high point of 79 percent in 1957 and drifted steadily downward to a low of 68.6 percent in the early 1970s. More recent trends suggest a slow increase in the proportion of industrial performance, which has risen to over 73 percent and has maintained nearly that share over the past eight years albeit with slight recent declines.

While the academic community's performance varied between 6 and 8 percent before 1960, there has been a slow but steady increase in the percentage of R&D performed in this sector, with recent levels reaching 14 percent. This total includes the R&D performed at the university-managed Federally Funded Research & Development Centers (FFRDCs). Since the early 1980s, this sector's share of performance had been in slight decline, although there has been a reversal of this trend in the most recent five years. Such a reversal has resulted in part from industrial initiatives (see later). For most of the 1960–80 period, other nonprofit organizations, including Battelle, increased their share of performance of R&D from 2 to about 3.6 percent of the total, again with recent declines in that share.

It should be noted that federal funding supports research performed by all sectors. Currently, over one-fourth of federal R&D funding supports intramural R&D; almost one-half supports industry; a little more than one-fifth supports colleges and universities (through direct grants and contracts, as well as through the FFRDCs); and the rest, slightly less than 4 percent, supports other nonprofit organizations. Industry absorbs almost all of its own funding, either intramurally or by contracting with other industrial performers. Its contracts and grants to colleges and universities exceed those to other nonprofit institutions by over 80 percent. Other nonprofits finance both themselves and academic institutions about equally, while colleges and universities absorb all the funds they originate.

TABLE 1. SOURCES OF R&D FUNDS AND PERFORMERS OF R&D, UNITED STATES, CALENDAR YEARS 1960–1988

(Millions of Current Dollars)

Year	Total R&D	Sources of Funds				Performance [a]			
		Federal Gov't	Industry	Colleges and Universities [b]	Other Nonprofit [c]	Federal Gov't	Industry	Colleges and Universities	Other Nonprofit [c]
1960	13,523	8,738	4,516	149	120	1,726	10,509	1,006	282
1961	14,316	9,250	4,757	165	144	1,874	10,908	1,173	361
1962	15,394	9,911	5,123	185	175	2,098	11,464	1,374	458
1963	17,059	11,204	5,456	207	192	2,279	12,630	1,611	539
1964	18,854	12,537	5,887	235	195	2,838	13,512	1,904	600
1965	20,044	13,012	6,548	267	217	3,093	14,185	2,103	663
1966	21,846	13,968	7,328	304	246	3,220	15,548	2,345	733
1967	23,146	14,395	8,142	345	264	3,396	16,385	2,594	771
1968	24,605	14,928	9,005	390	282	3,494	17,429	2,868	814
1969	25,631	14,895	10,010	420	306	3,503	18,308	2,950	870
1970	26,134	14,892	10,444	461	337	4,079	18,067	3,072	916
1971	26,676	14,964	10,822	529	361	4,228	18,320	3,216	912
1972	28,477	15,808	11,710	574	385	4,590	19,552	3,383	952
1973	30,718	16,399	13,293	613	413	4,762	21,249	3,701	1,006
1974	32,864	16,850	14,878	677	459	4,911	22,887	3,888	1,178
1975	35,213	18,109	15,820	749	535	5,354	24,187	4,396	1,276
1976	39,018	19,914	17,694	810	600	5,769	26,997	4,876	1,376
1977	42,783	21,594	19,629	888	672	6,012	29,825	5,451	1,495
1978	48,129	23,876	22,450	1,037	766	6,811	33,304	6,342	1,672
1979	54,933	26,815	26,082	1,198	838	7,417	38,226	7,296	1,994
1980	62,594	29,453	30,914	1,326	901	7,632	44,505	8,307	2,150
1981	71,836	33,374	35,946	1,555	961	8,425	51,810	9,301	2,300
1982	79,364	36,512	40,101	1,735	1,016	9,141	57,995	9,803	2,425
1983	87,280	40,691	43,524	1,936	1,129	10,582	63,403	10,620	2,675
1984	97,793	45,377	49,107	2,107	1,202	11,572	71,470	11,741	3,010
1985	107,757	51,668	52,358	2,377	1,354	12,945	78,269	13,223	3,320
1986	112,495	54,330	53,949	2,789	1,427	13,535	80,629	14,826	3,505
1987	117,882	56,391	56,722	3,145	1,624	13,413	84,600	16,284	3,585
1988[d]	124,915	59,200	60,530	3,470	1,715	14,500	89,400	17,400	3,615

Source: National Science Foundation

(a) The R&D performance of Associated Federally Funded Research & Development Centers (some administered by industry, some by colleges and universities, and some by other nonprofit organizations) has been combined with that of the administering institutions.
(b) As souces of funds, these include state and local government funding.
(c) All other nonprofit institutions.
(d) Preliminary estimates by NSF.

In Table 1 we summarize the latest NSF time series on the sources of R&D funding and the volumes of R&D performance. During the interval since 1960, total R&D dollars (not adjusted for inflation) have increased over ninefold. Federal funding has multiplied by a factor of 6.9 and federal performance has increased by a factor of 8.4. In terms of constant dollars, total R&D expenditures almost doubled from 1960 to 1988, and federal performance has increased by over 26 percent (see Table 6).

Also noteworthy is the high ratio of academic performance to academic funding. In the later years of this period, colleges and universities have provided about one-sixth of the total support for their own R&D activity, with much of the remainder (about 90 percent) coming primarily from the federal government. In recent years, this ratio has tended to decrease, not only as a result of some reduction in selected federal programs but also because of an increase in academic funding. As suggested earlier, this latter is largely a "book-

keeping" artifact created by the manner in which university funds are ascribed to the universities, rather than to the ultimate original sources. More will be said about this in later sections of the Forecast.

Beginning in 1968, there was a distinct change in the rate of growth in R&D, manifested by a leveling in current-dollar federal funding. This phase of the recent past seems to have ended with 1971, when current-dollar expenditures resumed an accelerating growth trend more nearly like that before 1968. As anticipated in the last two years' Forecasts, there is a continued growth of total real R&D support, although the rate of growth has slowed. Present trends even suggest that the total real R&D support could go through a short-term reversal. Whether this will happen will depend upon a number of factors to be elaborated upon later in this report.

The continuing transition in the support and performance of R&D, to which we referred in earlier Forecasts, has had a significant impact on the patterns within the overall R&D enterprise. The federal government has restructured major programs in energy and social services, both coming as results of *actions* and *philosophy*.

In addition, there have been changes in the structure of federally supported R&D. In particular, the budgets for basic research—much of which is directed ultimately toward defense applications—have shown a steady increase, growing at a rate of about 8 percent per year (in current dollars). However, the portion of federal R&D dollars directed toward truly basic research appears to have been declining in recent years.*

The changing emphasis by the federal government has been translated to the encouragement of selected R&D programs within the private sector, the determination to let the marketplace decide the most fruitful areas for private investment, and the return to state and local government those functions which are deemed most appropriate for state or local action, along with the research necessary to support the execution of those functions.

Presently, the strongest federal action, as we shall see in later sections of this forecast and analysis, continues to be in areas of fundamental concern to the central government, as perceived by the Administration: (1) national defense; (2) technological competition from our trading partners; (3) health; and (4) the environment for economic growth.[†]

*One must use caution, however, in attempting to draw too many conclusions based upon the most readily available statistics. Two problems arise: (1) the demarkation between "basic research" and "applied research," as well as that between "applied research" and "development," is not uniformly applied; and (2) the actual detailed surveys are not sufficiently accurate, reproducible, or recent to provide much confidence in the details.

[†]The extent to which federal actions can influence these areas will continue to be dependent upon a number of different factors, including the response to expanded military and/or diplomatic tensions—or reliefs—throughout the world, and the pervasive question of the massive national debt.

Forecast for 1989

During calendar year 1989, Battelle expects the total current dollar volume of R&D activity to be higher than the 1988 level estimated by NSF. A comparison of Battelle's 1989 forecast with the last available NSF estimates for 1988 is shown in Table 2. The 1989 forecast is shown in its historical setting in Table 1 and Figure 1.

Referring to Table 2, we estimate the total calendar year 1989 R&D volume to be $129.2 billion, a 3.43 percent increase over the NSF estimates for 1988. It is expected that part of this increase will be absorbed by continued inflation (which we estimate to be only 1.2 percent from 1988 to 1989 for R&D).

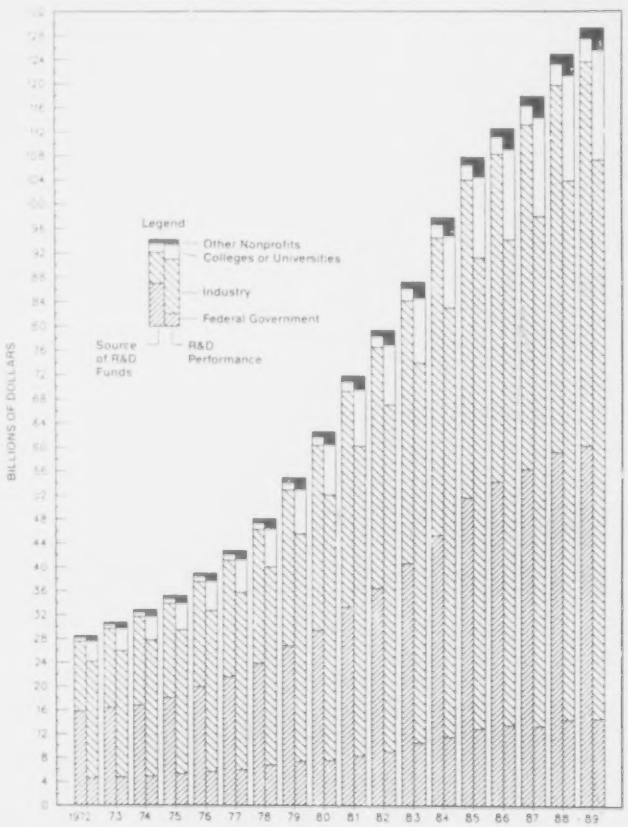

FIGURE 1. R&D FUNDING AND PERFORMANCE BY SECTOR, 1971-1988

TABLE 2. ESTIMATED R&D EXPENDITURES BY SOURCE OF FUNDS AND BY PERFORMERS, U.S. CALENDAR YEARS 1988 AND 1989

(Millions of Current Dollars)

Source of Funds	Performer				Source Totals	
	Federal Government	Industry	Colleges and Universities	Other Nonprofit	Dollars	Percent of All Funds
1988 NSF ESTIMATES						
Federal Government	14,500	30,200	12,200	2,300	59,200	47.39
Industry	—	59,200	850	480	60,530	48.46
Colleges & Universities	—	—	3,470	—	3,470	2.78
Other Nonprofit	—	—	880	835	1,715	1.37
Performer Dollars	14,500	89,400	17,400	3,615	124,915	100
Totals Percent	11.61	71.57	13.93	2.89		
1989 BATTELLE FORECAST						
Federal Government	14,671	30,783	12,598	2,278	60,330	46.70
Industry	—	61,887	916	505	63,308	49.00
Colleges & Universities	—	—	3,756	—	3,756	2.91
Other Nonprofit	—	—	928	878	1,806	1.40
Performer Dollars	14,671	92,670	18,198	3,661	129,200	100
Totals Percent	11.36	71.73	14.09	2.83		
PERCENTAGE INCREASES OVER 1988 ESTIMATES						
Federal Government	1.18	1.93	3.26	(0.96)	1.91	
Industry	—	4.54	7.76	5.21	4.59	
Colleges & Universities	—	—	8.24	—	8.24	
Other Nonprofit	—	—	5.45	5.15	5.31	
Performer Dollars	1.18	3.66	4.59	1.27	3.43	

In connection with this forecast, several important factors must be recognized. First, the total current-dollar projected increase includes an inflation factor that depends primarily on the inflation rate as it applies to R&D alone. As will be noted in the discussion of the Cost of Research Index, this inflation factor is fundamentally different from that associated with the more familiar Consumer Price Index.

In addition, it is apparent that concerns over the federal budget have influenced the appropriations bills for the 1989 federal budget. Furthermore, since part of the calendar year 1989 will come during the next fiscal year (1990), the budget process throughout this current calendar year will have a continuing effect on total expenditures. Finally, industrial support for R&D will continue to be affected by previous years' sales and earnings and should be expected to increase at a moderate rate. The passage of the new tax laws, with a modified continuation through 1989 of the R&D tax credit, could have a direct effect on the extent to which industry supports R&D. However, as argued in previous Forecasts, the support of R&D should not stem from a desire to decrease tax liabilities. It is, of course, more logical to increase R&D expenditures in search of long-term profitability and survival. It will also be seen in later discussion that industrial support may be affected by industry's short-term outlook, the stock market dislocation of late 1987, and the falling dollar.

In using Table 2, the reader should keep clearly in mind all the distinctions made by the table headings. For instance, in the *column* headed "Industry," we see that the total amount of R&D expected to be performed by industry in 1989 will be $92.7 billion. Of this, $30.8 billion will be funded by federal agencies, and almost $61.9 billion by industry. On the other hand, the *row* headed "Industry" indicates that industrial sources of funds are expected to support about $63.3 billion of R&D. Of this, $61.9 billion will be performed by industry, $916 million by colleges and universities, and $505 million by other nonprofit organizations. Included within the "Industry/

Industry diagonal" element is that research and development which is supported by one industrial organization and performed by another.

Continued inflation is expected to characterize 1989, although the rate, as experienced in R&D, appears to be declining. In addition, there are many intangibles that favor continued increases in support, including the perception on the part of both federal and industrial decision-makers that R&D is vital to long-term economic health. The NSF estimated that current dollar total R&D activity rose by 6.0 percent from 1987 to 1988; we project a smaller increase, 3.4 percent, from 1988 to 1989. As will be shown in connection with the Cost of R&D Index, not all of this increase is expected to be absorbed by inflation.

With respect to the *composition* of R&D activity, the expected pattern continues to be one of year-to-year stability or very slow change. Defense-, science-, and technology-based problems; considerations of economic development; and foreign competition are expected to provide the major impetus for change. The proportionate composition of both funding and performance will change very little. The federal government will account for 46.7 percent of the total funding, as compared with 49.0 percent from industry. Industry will account for almost three-fourths of total performance. These two distributions for 1989 are summarized in Figure 2.

The Role of Federal Agencies

Since federal funding was historically the major source of R&D support (although it has been outdistanced by industry during much of the '80s), the forces likely to affect federal R&D budgets in Fiscal Year 1989 and beyond are important in the present Forecast. The federal budget for Fiscal Year 1989, which began on October 1, 1988, continued the emphasis of the Reagan years and set the stage for what might prove to be significant changes in subsequent years.

The decline in the rate of growth of federal support had been suggested in the last two years' Forecasts and is occurring, although for a mixed set of reasons. Earlier predictions from many quarters regarding the impact of the Gramm-Rudman-Hollings Act have not been fulfilled. R&D seems to have fared well both in the Administration and in Congress.

This is not to say, however, that researchers and research managers should be complacent, since the continued pressure caused by the deficit will bring about changes in the not-too-distant future. The slowing of the rate of growth of R&D should surely continue over the next two to three years. In addition, the budget process itself promotes uncertainty with regard to R&D planning by both government and industry.

In terms of both hardware and research, the significant increase in defense spending will be continued by the new Administration's commitment to established initiatives. In addition, preliminary budget plans through 1991 set a direction that suggests continued emphasis in this area, although perhaps with a decline in the rate of growth. There is no way of determining at this time just how the new Administration and the Congress will address these program areas in future years, or how actions on the 1989 budget will proceed. However, early indications from the Bush Administration are that the slowdown in defense spending—including R&D—may be partially offset by modest increases in other areas.

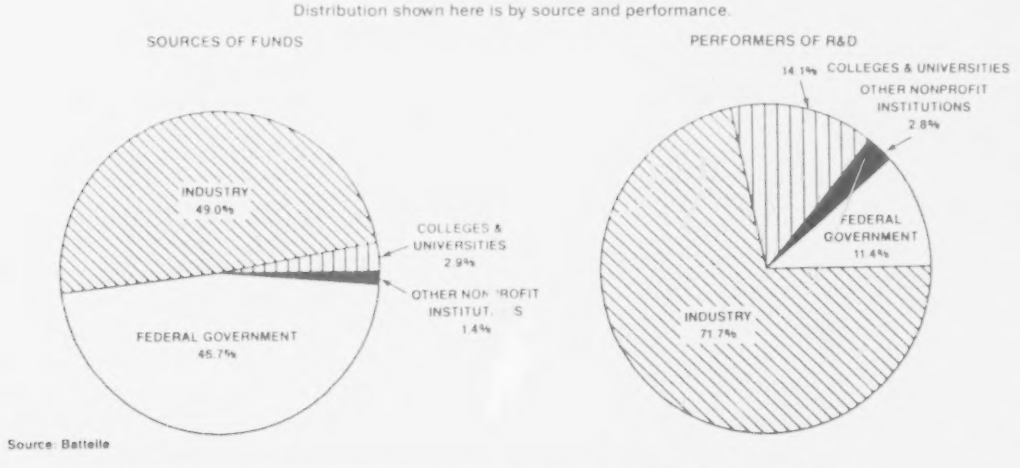

FIGURE 2. R&D EXPENDITURES IN THE U.S., CALENDAR YEAR 1989

Battelle projects that federal funding in calendar year 1989 will likely reach a level of $60.3 billion. This figure is based upon: (1) recent trends in federal budgeting, as reflected in NSF data series on R&D funding; (2) the relationship between federal funding and federal obligations; (3) the fact that three calendar quarters' funding will be determined by the FY 1989 appropriation; and (4) the modification of selected mission agency activities.*

The R&D-Minded Agencies

The big-money agencies in terms of total 1989 federal R&D funding will include the Department of Defense (DoD), the Department of Health and Human Services (HHS), the Department of Energy (DOE), and the National Aeronautics and Space Administration (NASA). Among the smaller agencies, the important suppliers of funds for extramural R&D are the NSF, the Department of Agriculture (DOA), the Department of the Interior (DOI), the Environmental Protection Agency (EPA), the Department of Commerce (DOC), and the Department of Transportation (DOT). Estimated percentage shares for conducting R&D in the early proposed budgets for FY 1989, and comparative estimates of the FY 1987 and FY 1988 plans, are:

	1987 Actual Authority	1988 Estimated Authority	1989 Estimated Authority
DoD	63.32	62.62	60.21
HHS	11.37	11.82	12.20
DOE	9.25	9.52	9.96
NASA	7.39	7.54	9.36
NSF	2.60	2.60	2.93
DOA	1.86	1.83	1.59
DOI	0.71	0.71	0.63
EPA	0.59	0.61	0.58
DOC	0.71	0.67	0.50
DOT	0.54	0.52	0.50
All Others	1.66	1.56	1.54

It is obvious from this listing that DoD continues to dominate the federal scene, accounting single-handedly for about three-fifths of the R&D budget. The Big Four (DoD, NASA, DOE, and HHS) account for over 91.7 percent of anticipated federal R&D expenditures, although the distributions within these four have changed slightly over the recent past (and are expected to do so in the future). The next six largest R&D-supporting agencies account for only 6.73 percent, and all others combined account for approximately 1.54 percent.

The continued increase in defense-related R&D derives from the development and acquisition of more advanced major weapons systems, and the Administration's commitment to highly sophisticated space-deployed defense approaches. The overall SDI program will continue to be heavily supported, although not at previous levels. The technical problems are quite formidable, but the complexities of such problems are not the only driving forces for increased expenditures. The commitment to pursue SDI-related R&D is presently well-established and is expected to continue in spite of continued progress in arms control negotiations.

The success of the SDI program is intimately tied to the total space program, which is expected to show modest gains after a brief hiatus. In addition, a new shuttle will be constructed to replace the *Challenger*, provided that budget problems can be resolved. There may even be further efforts to expand the shuttle fleet beyond that which was originally planned. Other NASA programs, such as the orbiting telescope and the space station, are dependent upon there being timely operations. The supplemental funds required would probably not affect the R&D budget as such. However, lacking such funds, the R&D programs that lead toward the utilization and support of new ventures in space would most likely be spread over a greater period of time, resulting in an effective decrease in NASA-funded programs.

The interdependence of the overall space program, with both defense initiatives and the "big science" astronomy and exploration programs in the advanced planning stages, continues to create a major dilemma in funding, planning, and the maintenance of a preeminent worldwide position in space. Competition from foreign space programs, especially on the commercial aspects, is expected to have impacts over the next few years and, unless the budgeting and planning process can proceed with a view toward long-term traceable benefits, the present stalling of the space program may result in permanent damage to this effort.

From 1972 to 1979, year-to-year changes in R&D budgets favored civilian programs over defense/space. Beginning with 1980, emphasis shifted back toward defense and space, especially the former.* Throughout the 1970s, the funding of energy-related R&D generally grew by larger increments than that of space or of most other civilian programs. When expressed as a fraction of total federal R&D support, a significant bulge in non-defense-related energy research began in 1973–74, reached a peak during the 1979–80 period, and has since declined. By 1988, the proportion of federally supported energy R&D had dropped to its 1973 value. It is expected that fed-

*Note that this estimate applies only to spending for the *performance* of R&D, and does not include any spending for R&D *facilities*.

*Although the share of total federal R&D in support of space research may appear to have been in decline, it is important to note that early NASA funding was almost *totally* termed as "research." When the shuttle was deemed to be an operational vehicle, the total support of the shuttle program was no longer classified as research.

erally supported energy-related research and demonstration programs will continue to decline, except for that portion which supports direct national defense interests and general science activities. As has been the case in the recent past, energy programs which involve short-term and/or low-risk R&D will probably have to be financed by private industry.

Factors Affecting Future Federal Support

There appears to be a continuing effort on the part of the federal government to increase funding of R&D, in terms of both support to basic national needs and the broadening of the technological base on which future growth is predicated. National security continues to be a principal driving force in furthering R&D spending. Economic growth, founded upon both basic and applied research, is expected to remain as an objective which requires direct and indirect federal support, with greater emphasis on the latter.

Federal efforts in energy research will continue to serve basic research that is inappropriate for industrial support, or that represents such long-term investments that no industrial applications are expected in the near future. Additional emphasis on high-energy basic physics research may be forthcoming, with plans for the next generation of particle accelerators already under way. One of the most sought-after big science projects in recent years has been the Superconducting Supercollider (SSC). Proposal evaluation finally resulted in the selection of the Texas site. There is no doubt that, all else being equal, this award can have significant impact upon R&D. However, all else is *not* expected to be equal, with concerns for balanced budgets and government cutbacks tempering the original enthusiasm. Much of the near-term support for the construction and operation of the SSC may be sacrificed during the forthcoming federal budgets, and these in turn will be influenced by the new Bush Administration. Effort will continue on the design parameters and on other preconstruction aspects of the project.

There are indications that industrial support will be growing in biological sciences (as is evidenced by increases in industrial funding at universities); and the federal government will continue to commit substantial resources toward this and allied fields. Budget-trimming efforts, especially as they apply to health and agriculture, have been largely cosmetic in recent years. They generally have been offset by Congressional action to reinstate various programs in such areas. Even the most ardent critics of the budget continued a "business as usual" approach during the most recent election, and will probably not pursue significant budget cuts in the next year. Early indications even suggest that the basic themes of the Bush Administration would translate into greater support for health and agriculture, as well as other social programs.

Several years ago, there was concern that federal funding of R&D might shift from extramural contract/grant support to intramural research performance utilizing the capabilities of the extensive federal laboratories and the Federally Funded Research and Development Centers. There is little evidence that any shift from extramural to intramural programs had been made through 1988. Furthermore, we anticipate that any such changes would be relatively small, and slow in coming. The overall shares in federal funding of both the truly intramural and the university-operated FFRDCs have been declining, as shown below:

Percentage of Federal Funds Expended

	Federal Laboratories	University-Operated FFRDCs
1978	28.53	20.00
1979	27.66	20.62
1980	25.91	21.53
1981	25.24	21.03
1982	25.04	19.82
1983	26.01	18.96
1984	25.50	18.83
1985	25.05	18.57
1986	24.91	19.53
1987	23.79	20.44
1988	24.49	20.61
1989	24.32	20.88

Over the past few years, various studies have been commissioned to review the operations of the federal government and to identify cost-saving actions that could be taken. These efforts have been well-meaning and, in many instances, have come to conclusions that seem quite reasonable and, in large part, even do-able.* Among the recommendations made by the Grace Commission and the Packard Report were inferences relative to the disposition of the federal laboratories and—by extension—the FFRDCs.

*Regarding the outputs of these studies, there are three points that should be considered. First, many recommendations were largely based upon a review and observation of individual activities without attention to the overlap and/or integration among activities. Second, the recommended changes stressed short-term payoff, rather than long-term costs and benefits, including effects on productivity, utility of outputs, and indirect—yet very important—economic impacts. Finally, much of the work was done with the perspective of the "outsider" business manager, without an appreciation of the (real or imagined) difficulties that would be faced in implementation of the recommendations. None of these criticisms is sufficient, however, to diminish the importance of the effort or to decrease the efforts at implementation.

The arguments for change within both types of institutions usually are made in terms of cost savings that result from industrial management, and of accelerated translations of research from laboratory to the marketplace. Conversely, the arguments against change reflect concern about private ownership and exploitation of publicly supported R&D and intellectual property, as well as the potential estrangements of laboratories from the mission agencies they are intended to support.

We expect there will be a continued consideration of the issue of privatization. The Reagan Administration had supported the idea, in concept, although no major efforts came to fruition. To be sure, there are significant candidates for privatization, with the most attention having been given to the National Technical Information Services (NTIS). However, strong pressures have precluded any initiatives with NTIS, including language in the Congressional appropriations bills which removed NTIS from consideration. The overall movement to carry through on privatization has received some setbacks; however, over the next decade, a significant number of institutions conceivably could undergo such a conversion.

Along with the developments already discussed, continued effort is being made to promote federal laboratories as resources available to both federal and non-federal markets. However, there are conflicts that may influence the outcome of this effort. While federal regulations permit and encourage response by federal laboratories to external needs, there also are several real and perceived restrictions. Whether federal laboratories will be more heavily involved in R&D as a result of the Stevenson-Wydler Act remains to be seen.* There is little evidence that the federal laboratories so far have been heavily involved in "external" activities. To the extent that they are, there are no reliable statistics regarding the support (on a reimbursable basis) or performance of R&D outside the laboratories' specific missions.

It is expected that some of the federal laboratories will take a more aggressive posture in marketing their services under the aegis of the Stevenson-Wydler Act. Faced with potential decreases in support, the laboratories may initiate more "industrial liaison activities," following the posture adopted by the universities in the early 1980s. They will, however, face basic problems related to the mandate that the federal laboratories should not be competing with private industry.

One cannot overlook the impact that federally sponsored R&D has had on the national economy. Major government-sponsored programs in defense, space, health, energy, and other areas have assisted in fulfilling the fundamental responsibilities of the federal government, and they have also spurred development in almost all sectors of U.S. industry. The implementation of research results—many of which were originally supported by federal funds—has created an economy with strength and versatility to match any found in the world. The extent to which federally supported research can be and has been used is influenced by a vast array of factors, such as the restrictions placed on the use of intellectual property, the complexity of tax laws, and the demands and expectations which are inherent in a free-market, public-ownership economy.

As federal efforts are made to enhance the competitiveness of U.S. industry, it is appropriate to point out that the federal government cannot do it all, and should not be expected to do so. The responsibilities for increasing productivity, for diversifying the products of manufacturing, and for meeting the challenges by other countries rest equally on all public and private sectors. When faced with an interlocking worldwide economy in which developing countries are expanding their own presence in the market, it is incumbent on the federal government to (1) maintain a posture of continued R&D investment, creating an improved stockpile of usable technological outputs and (2) provide an atmosphere wherein the fruits of these investments can be more readily adopted and adapted for commercial benefit.

As noted in last year's Forecast, we expected that the role of the federal government in both the near- and long-term futures would be debated vigorously during the presidential election campaign. Insofar as the role of science and technology is concerned, this did not happen.

Battelle has been preparing this annual forecast since 1969, through the terms of four presidents—each coming into office with different views of the roles and responsiblities of the federal government. This year will be different, however, because it is the first time since 1960 that a president will be succeeded after having served two full terms in office. The past eight years have seen changes in the activist nature of the federal government, the position of the United States in world trade, the buildup of massive deficits, the deregulation of major segments of business, the shifting in the nature of the economy, and the restructuring of the tax code.

The impacts and influences of the outgoing Administration will be felt for at least the next two years, as the forth-

*The Stevenson-Wydler Act was designed to facilitate the transfer of technology from government laboratories to a wide range of users. It contained provisions for reimbursable services, and was expected to increase the utilization of government-developed technology. The Act formalized many existing technology transfer programs initiated by various federal agencies, and has been expanded and modified by various "Technology Transfer Acts." Much impetus for Stevenson-Wydler came from the public interest associations that represent state and local governments. To date, there have been mixed reviews regarding the effectiveness of the Act.

coming budgets will make clear. The new Bush budget will continue to reflect the general thoughts and thrusts of the Reagan Administration. Changes may include a paring of defense-related research, and the distribution of available funds to other areas. In any event, these changes will be incremental and should not lead to major disruptions in ongoing programs.

In summary, one must not lose sight of the fact that sooner or later, federal budget problems have to be resolved. Almost all areas of federal support should be subject to sacrifices, including decreases in overall R&D funding. Inasmuch as R&D has made major contributions to the welfare and economic growth of the country, it is hoped that federal agencies with policy, budget, and taxing responsibilities will appreciate its role and take whatever initiatives are necessary to encourage it.

The Role of Industry

NSF data indicate that during the period 1980–1988, industrial support of R&D was greater than federal support, although the roles were reversed in 1986. Battelle projects that industrial funding in 1989 will again exceed federal funding. As has always been the case, industry will be by far the predominant R&D performer.

For 1988, the NSF has estimated that industry provided 48.5 percent of total funding and performed almost 71.7 percent of all R&D work (see Table 2). Battelle's forecast for 1989 changes these shares almost imperceptibly to 49.0 and 71.7 percent, respectively.

The NSF data base indicates that industry has been the second-fastest growing sector. Table 3 compares sectoral growth rates for the nine-year interval 1979–1988. It is of particular interest that, as sources of funds, both industry and colleges and universities have grown quite significantly. The expansion of industrial support is understandable in terms of the forces that have been driving industry over the past few years. The rapid increase in university funding, however, relates to the manner in which R&D statistics are collected and accounted for.

Battelle projects considerable differences among the 1988–89 sectoral growth rates. Total R&D expenditures are expected to grow by 3.4 percent; industrial funding and performance are expected to increase by 4.6 and 3.7 percent, respectively.

Industrial funding is expected to rise from an NSF estimated level of almost $60.5 billion in 1988 to $63.3 billion in 1989. Industrial performance will rise from $89.4 billion to almost $92.7 billion. Note that the increases in both

TABLE 3. SECTORAL GROWTH RATES IN FUNDING AND PERFORMING R&D, 1979–1988

	1979 = 100.0%		
Sector	Source	Performer	Ratio s/p
Total United States	227.4	227.4	1.000
Federal Government	220.8	195.5	1.129
Industry	232.1	233.9	0.992
Colleges & Universities	289.6	238.5	1.215
Other Nonprofit	204.7	181.3	1.129

Source: Derived from Table 1

funding and performance by industry are smaller than in previous years, as had been anticipated in the 1988 Battelle forecast.

Industrial research, as it applies to the accomplishment of industrial and governmental objectives, is both a means to an end and an end in itself. While the continuing profit motive in a competitive marketplace spurs R&D for individual industry's benefit, so also does the industrial system provide a mechanism for the execution of programs of high national priority. In view of (1) the continuing emphasis on innovation; (2) the application of advanced control technology to mature industries; and (3) continued tax incentives for industrial R&D, Battelle's 1989 forecast continues a new area of analysis, namely, the comparative federal and industrial funding of R&D in major groups of industries.

Using data derived both from NSF sources and from interpolation or extrapolation of the McGraw-Hill surveys, we have estimated the degrees to which industrial and federal funds will support industry R&D performance (see Table 4).

This distribution between federal and industrial funds is, unfortunately, somewhat misleading because it does not address the more critical question of support for R&D among different lines of business. With R&D expenditures grouped according to major Standard Industrial Classification (SIC) codes, it is not possible to distinguish, for example, electronics research performed by a well-known electronics company from that performed by a subsidiary of a major company whose principal product line (and SIC code) falls into an entirely different category. Conversely, this determination does not isolate, for example, research in chemicals which is performed within the rubber or petroleum industries.

More specific information on the R&D expenditures within industry is extremely difficult to collect and assess, especially in those cases where (1) individual companies are

TABLE 4. ESTIMATED SOURCES OF FUNDS FOR INDUSTRIAL PERFORMANCE OF R&D BY BROAD INDUSTRIAL CLASSES, 1989

(Millions of Current Dollars)

	Federal Funds	Industry Funds	Total Funds	% Federal
Aerospace	15,647	3,511	19,157	81.67
Electrical Machinery and Communications	7,928	10,618	18,546	42.75
Machinery	1,669	10,457	12,126	13.76
Chemicals	381	11,134	11,515	3.31
Autos, Trucks & Parts, & Other Transportation Equipment	1,982	9,431	11,413	17.37
Professional & Scientific Instruments	991	5,531	6,522	15.19
Petroleum Products	21	2,068	2,089	1.00
Rubber Products	313	930	1,243	25.17
Food & Beverage	0	1,172	1,172	0.00
Pulp and Paper	0	1,009	1,009	0.00
Iron & Steel	73	732	805	9.07
Fabricated Metals	136	629	764	17.74
Nonferrous Metals	42	600	642	6.50
Stone, Clay & Glass	21	601	622	3.36
Textiles	0	176	176	0.00
Other Manufacturing	21	1,049	1,070	1.95
Total Manufacturing	29,223	59,648	88,871	32.88
Non-Manufacturing	1,565	2,206	3,770	41.50
TOTAL	30,788	61,854	92,641	33.23

engaged in a variety of research programs to support different lines of business, or (2) companies' R&D is diversified among an array of products and processes within the same line of business. The extension to the case where both industrial and federal moneys are involved is similarly difficult. Detailed data are available relative to government support of R&D by industry and by area of research. However, the comparison with expenditures of industries' own funds cannot be pursued without dissecting specific industrial R&D budgets.

These latter are, of course, almost always considered as confidential and proprietary information. Over the past few years, Battelle programs have been directed toward analyzing R&D within broad industrial classes, and thereby providing specialized information which assists in the R&D planning, management, and assessment activities of the cooperating industries. It will be quite some time, however, before sufficient detail is collected for a large number of R&D-intensive industries, and for a more nearly accurate picture of the government/industry split—with all its implications—to emerge. More will be said of this in the section on Improvements in Information Resources.

An additional caveat should be noted relative to the ready availability of R&D data. A most convenient source of data on R&D investment is the annual *Business Week* Scoreboard, usually published near the middle of the calendar year. The Scoreboard provides compilations of total R&D data for the major publicly held corporations, along with associated trends and ratios. While these data lend insights into broad patterns of support, they do not include information on privately held and/or small businesses. It is generally held that these latter firms represent a most important element in the areas of applied research, commercialization, and new-job formation.

The performance of R&D by industry will be financed either by the federal government or by industry itself (Tables 2 and 4). Industrially funded work will mostly be done by industry either internally or contracted out to other industries. A very small amount (less than 2 percent) will be done extramurally by universities and other nonprofit institutions. The nonmanufacturing industries perform relatively little R&D but, as noted in Table 4, approximately 41.5 percent of the support for this activity is provided by the federal government. In contrast, R&D is more heavily self-funded by (and in) the manufacturing industries where, on the average, about 33 percent of the total performance is supported by federal funds.

The leading industry in the nation for R&D will again be the aerospace industry, projected to spend approximately

$19.2 billion, with more than four-fifths of its funds coming from federal sources. In second place will be the electrical machinery and communications industry, projected to spend $18.5 billion, of which 42.8 percent is federally funded. Since 1980, these two major sectors have dominated and interchanged between first and second place. Further appropriations for defense systems, as well as anticipated growth in the computer and communications industries, are expected to continue the dominance of these two broad industrial classes.*

Aside from aerospace, where federal support of R&D is dominant, there are no industry groups in which more than half of the R&D performance is expected to be directly supported by federal grants and contracts. In addition to electrical machinery, communication, and the rubber industry, no other industries are expected to receive as much as 18 percent of their funding from federal sources.

Finally, we call attention to the fact that the total industry funding shown in the third column of Table 4 makes no distinction between R&D performed in-house and that contracted out to other industrial firms.

Factors Affecting Future Industrial Support

Over the past few years, industrial spending on R&D has increased significantly although, as anticipated in recent years' Forecasts, the rate of increase in 1989 will be slightly lower. Recent spurts in industrial support had been the result of a healthier economy, increased sales and profits (both early indicators of R&D fund availability), relaxation of perceived barriers to cooperative research, and—to a small degree—the R&D tax credit enacted in 1981. However, other factors have influenced the present near-future support for R&D. As one looks at these factors there are several points which must be emphasized, especially if we are to appreciate the lessons of history and plans for the future.

Industry is not driven solely by technology and its availability, nor should it be. The U.S. R&D enterprise has, over the past 30 years and more, provided an incalculable wealth of understanding, a veritable flood of knowledge related to the properties of materials and the devices and systems that can be developed from them. Almost every sector of the economy has developed a backlog of information and know-how that can continuously enhance all manner of processes and products. It is well within our grasp to improve health care; to access, process, and utilize growing volumes of information; to implement processes and products that would in the long run save all manner of resources; to improve the capacity for growing, processing, and distributing food products; to reduce pollution and take advantage of waste; and to bolster the overall physical infrastructure.

But the availability of technology and the fruits of R&D do not determine the extent to which technology is applied. The use of new technology can carry significant cost—including the direct cost of acquiring know-how, and the unamortized costs of in-place processes. Moreover, applicable long-term debt service adds another element in the decision to adopt new processes or approaches. The ultimate resolution then comes down to a series of alternatives and considerations: to adapt or not; the cost of innovating as contrasted with the cost of *not* innovating; the issue of potential short-term losses vs. long-term profitability or even survival.

With these considerations as background, it is now appropriate to note several points that have had an impact on recent industrial support of R&D, and which are expected to affect the near-term future support.

"Reindustrialization"—the rallying cry a few years ago—conjured up pictures of massive investments in new plants and equipment designed to result in a recapture of basic markets that had been lost to foreign manufacturers.

"Competitiveness"—the more recent driving force—again spurred rounds of speeches and challenges to industry, appealing to management and labor alike to modernize operations, increase productivity, enhance profitability, and reduce trade imbalances.

The philosophical cheerleading may have driven selected firms to make the necessary investments to become more competitive and increase productivity. But other forces have had their influences on industrial R&D expenditures. Specifically, the commitment to long-term growth and strength has been affected by significant return to the short-term outlook that pervaded industrial management only a few years ago. The concepts of research and innovation are basically incompatible with the near-term profit objective. Thus, much effort has been directed toward alternative means of achieving this end, namely, the continued restructuring, buying of companies, and selling of nonrevenue producing components, and "the art of the deal". Manipulation, rather than innovation, has become the route to selective success.

The merger and acquisition practice has had some impact on R&D funding, and this is manifest in at least four ways: (1) the reduction or elimination of R&D spending and facilities, while aiming for short-term profit; (2) the use of resources to pay off debt incurred by acquisition; (3) the defensive

*Note here, for example, that two of the major aerospace and electronics contractors—EDS and Hughes Aircraft—are not represented in these compilations or estimates. Recent acquisitions have resulted in these companies' R&D efforts now being incorporated into other industries' totals.

approach of buying back stock to fight takeover attempts; and (4) the reduction of duplicate operations in intra-industry mergers. The last factor represents a reduction in total funding without a significant loss of technology-development potential. The first three are obviously detrimental to technical growth.

Industrial support of R&D usually lags decision-making by one to two years. Funding in 1989 will thus be influenced by events and uncertainties that were evident in 1987 and 1988. The major readjustment of the stock market and the mere thought of a changing administration were partially responsible for the reduced rate of growth of R&D spending.

For the past two years, this Forecast has expected such a slowdown, perhaps even resulting in *decreases* in the constant dollar support of R&D. Such decreases certainly would not be unprecedented, there having been a similar reduction in the early and mid 1970s (see Figure 3). If such a turnaround were to come, it would probably not last long, barring unforeseen major dislocations in the economy, a renewed perception of a federal government that is "friendly" to business will mostly reinstate confidence and the resultant support to R&D.

A final word on the effects of mergers and acquisitions carries more of a warning than a forecast. In those cases where acquisitions result in significant debts, there is concern that debt service—which has present-day obligations—would consume revenues that might normally have been directed to research (with the concomitant longer-term payoff). The consequent reduction of resources used to obtain a technological advantage—through either direct R&D or direct purchase of technology—will then have adverse effects upon competitive position and survival. In times of tight budgets, R&D might be considered a "deferrable luxury"; however, the ever-changing and advancing nature of technology is such that opportunities deferred can quickly become alternatives lost.

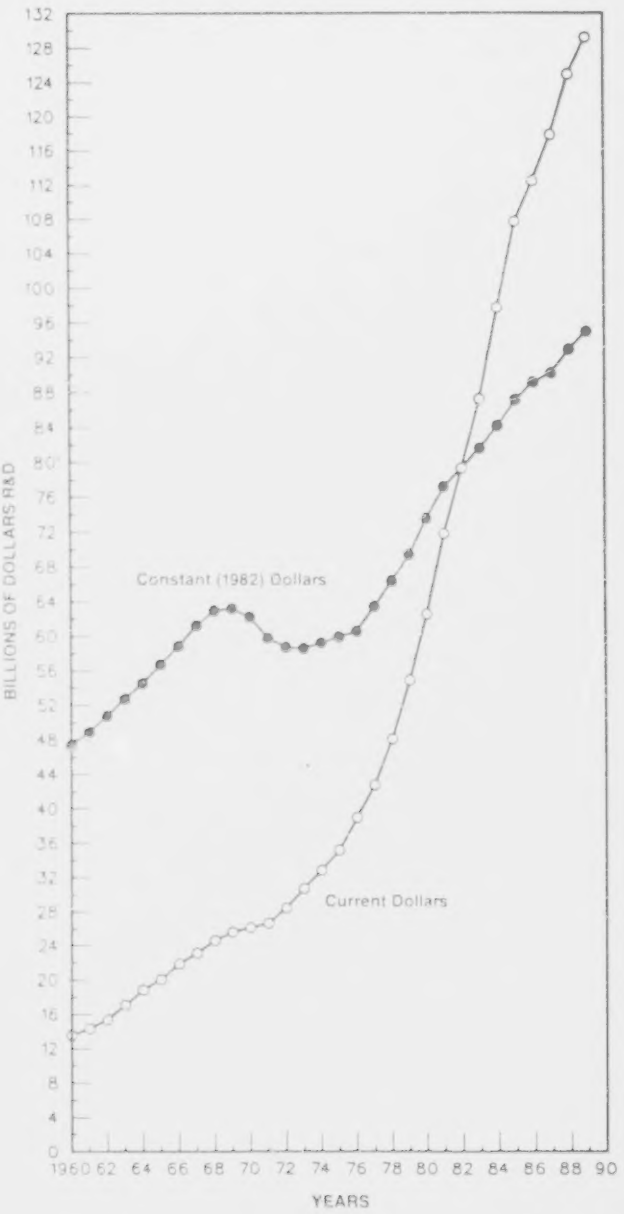

FIGURE 3. TOTAL R&D EXPENDITURES, 1960-1989, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1982 = 100%)

The Role of Academic and Other Nonprofit Institutions

Nonprofit institutions—colleges, universities, and other types—both fund their own research and conduct research funded by federal agencies and/or industrial firms. It is generally conceded that a significant portion of all basic research as well as some of the longer maturing applied research, is conducted in this sector.

In 1960, the academic and other nonprofit institutions financed from their own resources (including endowments and direct state and local funds) approximately 2 percent of all R&D (see Table 1), while actually performing over 9.5 percent of the total. For 1989, Battelle forecasts that these same nonprofits will provide 4.31 percent of all funding and will perform almost 17 percent of the total (see Table 2). These percentages are slightly higher than the corresponding ratios for the 1988 NSF estimates.

The growth in nonprofit R&D performance has been accompanied by minor shifting within the nonprofit sector. In 1960, the academic community accounted for 55.4 per-

cent of total nonprofit funding and performed 78.1 percent of the nonprofit total. For 1989, Battelle forecasts 67.5 percent and 83.2 percent, respectively. A significant portion of the increase in academic support and performance derives from the increase in major industrial support ("directed endowments") associated with specialized areas of research such as electronics, artificial intelligence, and biological sciences.

There are two distinct groups of "other" nonprofit organizations. These are the foundations and associations which exist for various charitable and other purposes, and the nonprofit research centers which may or may not perform under contract. The first group funds a great deal of research, through grants and contracts. These go both to members of the academic community and to other nonprofit centers. The second group acts in three ways: (1) a member may perform as a foundation; (2) it may fund its own research performance; and/or (3) it may perform under contracts (with government, industry, or other nonprofits).

From 1965 to 1980 other nonprofit performance has fluctuated slightly between 3.3 and 3.7 percent of total R&D. Since then, this sector has declined to less than 3 percent. For 1989, Battelle estimates that the other nonprofit sector will comprise 2.83 percent of total R&D performance. Furthermore, we estimate that 51.4 percent of other nonprofit funding will go to colleges and universities, with the remaining 48.6 percent being spent by the other nonprofit sector itself. The percentage of support to colleges and universities is slightly higher than in recent years.*

The total R&D performance in the other nonprofit sectors is not increasing as rapidly as in other performing sectors. However, as noted above, this sector is composed of quite diverse constituent organizations. As performers of R&D, the establishments within this sector range from institutions such as Battelle (engaged in a spectrum of technology development, commercialization, and management programs) to small nonprofit firms that act as delivery mechanisms and research arms for federal, state, or local government agencies, especially for social programs. The activities of these latter types of organizations have been significantly reduced in recent years. As might be expected, the extent to which agencies support research is roughly related to the magnitude of their operational programs. With large proportional decreases in, for example, federal funding of social programs, the concomitant decrease in research related to these programs has been felt by many nonprofit research organizations. Hence, it is not unexpected that the aggregate of nonprofit performers should display smaller-than-average growth rates, or, in fact, real declines in comparison with other performing sectors.

Early indications from the new Administration suggest that social/civil programs might receive small increases in the near future, partially offsetting the major cuts of recent years. It remains to be seen, however, whether the Congress and the Administration can agree upon such expansion.

Finally, in addition to contracts or grants to support research on industrial problems (the "industry funding of colleges and universities" shown in Table 2), there is another form of support, not yet reported in detail by the NSF, that must be noted. This is the industry/university arrangement which takes a form that more nearly resembles "directed endowments" than either a specific research contract or a general gift. The large multiyear programmatic grants are then accounted for as college and university self-funding.

Somewhat misplaced in the accounting for industrial support of university-based R&D is the recent trend of major industrial gifts to universities. While industrial support of R&D, as reported by the NSF, is largely defined to include only contracts and grants with specific projects, this definition neglects the substantial funds that had been used to "endow" an area of activity (e.g., robotics or biotechnology). Such funds are treated in much the same manner as state government appropriations to public institutions. They become the university's "own funds" and are not credited to their real sources. This lack of better definition serves to hinder investigation of the impacts of tax laws or other incentives on the university/industry interface.

R&D in the nonprofit sectors—particularly the colleges and universities—has been one of the mainstays of the growth of that basic knowledge that had led to the development of the total economy. In both public and private institutions, R&D has served both to expand understanding of science and technology and to play a critical role in the education process itself. Unfortunately, there is no totally reliable estimate of the amount of R&D that is actually conducted, or the relationship between the funding agencies and the performing institutions. Thus, one cannot develop reliable rationales or policies which relate to academic research, its support, and its important role in further advancing the objectives of an industrialized, technology-based society. As greater emphasis is placed on the issues of competitiveness and the most efficient use of total technical resources, a greater effort should be directed toward understanding the role that university research plays in the national economy and the incentives and barriers which influence utilization of this resource.

*We must be cautious in drawing conclusions from the available data on R&D in the university and other nonprofit sectors. The primary survey data from which we work have not been collected directly and in great detail for a number of years. The NSF data are fairly good estimates, but small differences can give rise to significant percentage errors.

The Cost of R&D Inputs

From an economic point of view, inflation can be defined as a general rise in the price of goods and services that is not offset by corresponding increases in quality. If the prices of everything tend to rise together, slowly and in the same proportions, and if individual incomes also rise in those same proportions, the relationship between money and goods/services changes in a fashion which is detrimental mainly to the holders of such fixed-dollar obligations as life insurance. On the other hand, when the prices of things bought with income rise faster than the incomes, structural imbalances occur which may be quite painful to particular sectors of the economy.

Goods Versus Services

Most considerations of prices tend to take place within the context of goods' prices (i.e., the prices of tangible things). The tangibility of goods makes it possible both to measure the quantity of their output and to estimate, within reasonable limits, changes in their quality. Thus, with respect to goods, there usually is agreement as to whether or not costs are rising faster than output, or prices faster than quality. That is to say, we tend to have general agreement that inflation is or is not occurring in the goods-related economy.

Services, on the other hand, are intangible. Therefore, we usually have greater difficulty achieving agreement that, in terms of any meaningful measure, the quantity or quality of service output is rising or falling. Thus, our only measure of many types of service output is the total amount of money that we pay for them—and that is a function of price and quantity, with no account taken of quality.

R&D, by definition a part of the "knowledge industry", is primarily a service activity, despite the fact that much of it ultimately becomes embodied in products. For this reason, we have no agreement as to what can be termed a "unit" of R&D output. Therefore, we cannot ascertain whether or not the "price" of R&D output is rising or falling. However, we can put a price on R&D inputs. For that reason, most discussions of the cost of R&D tend to be couched in those terms. Battelle has not yet given up hope of achieving a measurement of R&D output and from time to time has undertaken investigations which may lead to quantifying at least some kinds of R&D output. Nevertheless, such a measurement is not now available and the discussion which follows must be in terms of input costs.

In viewing the costs of R&D performance, it is tempting to contrast the "inflation" in R&D with the commonly used Consumer Price Index—the factor which provides a measure of general inflation—or to use the Gross National Product (GNP) deflator, as NSF does. To do so misses three basic points distinguishing R&D from the more general set of purchases. First, the CPI is based upon a defined average "marketbasket" purchased for general consumption, and the GNP deflator covers a somewhat broader range. However, purchases by R&D performers are from a much more specialized collection of goods and services.

Second, the education of scientists and engineers has a built-in bias for the acquisition and use of more sophisticated (and, hence, generally more expensive) materials, devices, and systems required for the conduct of research. Were it not for this factor of the research culture, technological advancement would not be so rapid.

Third, and perhaps most important, the very nature of research is such that the problems addressed by researchers are increasingly more difficult. The easy questions are always answered first, and the effort necessary to make incremental gains in the understanding and application of science and technology is ever-increasing. Thus, we generally expect that the "inflation rate", as applied to the conduct of R&D, will increase more rapidly than that of the average consumer purchases.

The "Cost of R&D Input" Index

In the absence of a measure of R&D output costs, many organizations, including the NSF, use the GNP deflator (from the national income and product accounts) as an indicator of changes in R&D costs. This index responds to the costs of both goods and services. R&D costs are made up primarily of service costs. Battelle researchers, therefore, feel that the GNP deflators probably have misstated rates of inflation with respect to R&D.

Several attempts have been made to determine the input mixes of typical R&D activities and to price each input, thereby generating standard weighted price indexes for R&D. To date, this approach has not been very productive, although such efforts continue and may eventually achieve success.

A pioneering effort to more directly measure trends and fluctuations in the cost of R&D was made by Helen Milton beginning in 1966.* Using information supplied by representative R&D performers, Milton compiled data on the total dollar cost of R&D per technical (professional) man-year.**

*See Helen C. Milton, "Cost of Research Index, 1920–1970", *Operations Research*, 20, 1–18 (1972).

**Milton said that "The 'technical man' is the professional scientist or engineer, plus his support".

Her series of cost indexes ended with 1970, using 1950 as the base year. Between 1970 and 1979 Battelle extended the Milton Index Series by means of annual estimates. Finally a new series of R&D cost indexes was introduced in the 1980 Battelle Forecast and Analysis. This new series, while conceptually similar to the Milton Series, is based upon a different body of data and does not show precisely the same year-to-year changes as the Milton Series and our earlier extensions of it.

The Battelle Cost of Research Index, displayed in Table 5, is based upon two series regularly published by the NSF: (1) the R&D performance figures, by sectors, that have already been discussed in connection with the Source/Performer Matrix (Table 2); and (2) estimates of the full-time equivalent numbers of R&D scientists and engineers employed by each performing sector. The ratio of costs to scientists/engineers for each sector provides the basis for the sectoral subseries, which are then weighted and combined into the all-sector average.

As derived from Table 5, Battelle's best estimates of recent increases in the total index are 2.1 percent for 1985–86, 3.6 percent for 1986–87 and 2.9 percent for 1987–88. We expect the cost of R&D to increase by about 1.2 percent between the estimated 1988 level (134.38) and the forecast level for 1989 (135.95) with the estimates stated in terms of the 1982 base.

Sector Comparisons of R&D Costs

During the interval 1982-89, costs of all R&D, as an average, are estimated to have risen by 36.0 percent. Increases in the individual performing sectors are expected to be: federal government, 55.2 percent; industry, 31.9 percent; colleges and universities, 45.4 percent; and other nonprofit, 29.4 percent. As noted, the 1988-89 cost increase for all R&D is estimated to be 1.2 percent. By sectors, the increases are estimated as federal, 1.3 percent; industry, 1.2 percent; colleges and universities, 1.3 percent; and other nonprofits, 1.0 percent.*

Trends in Real R&D Effort, by Sectors

If we take total expenditures and sector performance figures from Tables 1 and 2 and deflate them to constant 1982 dollars with the corresponding index numbers from Table 5, we can make parallel comparisons for each of the four performing sectors. These are shown in Table 6 and graphed in Figures 3 and 4.

In current (undeflated) dollars, total U.S. R&D expenditures have risen in every year of the period, even though the rate of increase fell sharply between 1969 and 1971. But the deflated (real effort) series before 1978 reached its peak in 1969, declined between 1969 and 1973, and moved generally sideways until 1977, when it exceeded $62 billion for the first time in eight years. We expect real R&D effort in 1989 to increase by 2.23 percent over 1988 and to reach a level that is 50.3 percent above its 1969 peak.

When we shift our attention to the performing sectors, we find that the recent upward drift of real R&D activity results from the behavior of the private sectors. The downturn or flat behavior in real expenditures that began after 1968–69 is clearly reflected by every sector. However, deviations in sector behavior emerged later, especially since about 1975. In government, the real performance series has recovered only slowly from its 1976 minimum and has not yet equaled its 1968 peak.

In the private sectors, industry reached its real low in 1972 and has since risen by 76.6 percent to its highest recorded value. The academic community reached a low in 1973. Since then, its real performance has risen by almost 69 percent and now stands well above the 1968 value. Other nonprofit institutions' real performance declined slightly from 1968 through 1970. Since that time, it has risen by 48.6 percent.

Finally, we turn to the data of Table 6 and the curves of Figures 3 and 4 to see the dramatic differences in the R&D trends among the four performing sectors. Since the lull of the early 1970s, industrial performance, funded by both government and industry, has been largely responsible for the real growth within the R&D enterprise. Using the same performance deflators as applied to the sources of funds, over the past decade, industrial support of R&D has increased at an average compounded rate of 3.51 percent per year, while federal support has increased at 2.73 percent per year on average.

The behavior exhibited in Figures 3 and 4 suggests that the real growth in R&D (and the economic development and expansion that result from it) has come from the applied research supported and performed by private industry. However, one cannot overlook the fact that such applied research and development must rest on, and evolve from, the basic research foundation—an activity that is primarily supported by the federal government (almost 64 percent).

Over the past few years, federal support has tended to shift more toward "development" and less toward basic and

*The estimates of the Cost of Research Index and its year-to-year change are quite sensitive to changes in the basic data on expenditures and manpower levels. Much of the input data are derived from NSF resources which, as noted earlier, are adjusted annually.

TABLE 5. BATTELLE COST OF RESEARCH INDEX* BY PERFORMING SECTORS, CALENDAR YEARS 1960–1989 (1982 = 100)

		Performing Sectors			
Year	Total U.S.	Federal Government	Industry	Colleges and Universities	Other Nonprofit
1960	28.54	23.03	30.76	20.42	35.28
1961	29.28	24.07	31.11	23.25	36.21
1962	30.33	25.64	31.78	26.02	37.50
1963	32.35	26.48	34.05	28.89	37.04
1964	34.57	31.57	35.57	32.21	36.50
1965	35.34	32.85	36.23	33.09	37.09
1966	37.12	33.02	38.43	34.60	39.24
1967	37.80	33.52	39.08	35.77	39.93
1968	39.09	33.68	40.61	37.95	39.07
1969	40.56	34.58	42.24	37.71	45.69
1970	41.99	39.67	42.80	39.22	48.11
1971	44.61	43.43	45.45	41.11	47.01
1972	48.46	49.07	49.14	44.14	48.62
1973	52.41	53.71	52.68	49.95	50.23
1974	55.47	55.29	56.30	51.05	56.29
1975	58.74	60.18	59.14	54.35	61.77
1976	64.41	71.04	64.29	58.36	65.19
1977	67.44	71.75	67.42	62.87	69.36
1978	72.49	78.29	71.54	71.29	74.46
1979	79.09	84.82	77.77	80.23	80.73
1980	85.07	85.49	84.39	87.92	87.05
1981	93.06	93.41	92.42	96.04	94.85
1982	100.00	100.00	100.00	100.00	100.00
1983	106.91	113.31	105.78	107.36	108.30
1984	116.08	122.31	115.11	115.25	119.69
1985	123.59	135.09	121.81	123.58	125.30
1986	126.14	140.35	122.88	132.58	127.95
1987	130.64	141.32	127.58	138.78	133.05
1988	134.38	153.26	130.40	143.58	128.18
1989	135.95	155.32	131.92	145.44	129.40

*Costs of performing R&D per scientist/engineer (full-time equivalence).
Source: Estimated by Battelle from NSF and Battelle data.

applied "research".* The federal government is still the major supporter of basic research, and trends in the federal budget indicate that this support will continue to be strong. In addition, there is a continuation of basic research support by industry. However, the volatility of those indicators (sales, profits, cash flow) which influence industrial R&D budgets precludes the stability needed for long-term planning. Policy- and budget-makers in all funding sectors should note very carefully the trends in basic research, since the conduct of such research forms the basis for future economic vitality and competitiveness.

Thus, the federal government, in any attempt to maintain the vitality of our technology-based and technology-influenced economy, should continually re-examine its policies relative to (1) the support of R&D, (2) the roles of the public and private sectors, (3) the factors which enhance or impede the progress of science and technology, and (4) the commitment to science education at all levels.

*One must be careful not to read too much into the data which are available regarding the divisions among basic and applied research, and development. It is at times difficult to make the distinction as to where one phase stops and the next takes over. Furthermore, the definition as applied by the supporter may be substantially different from that applied by the performer.

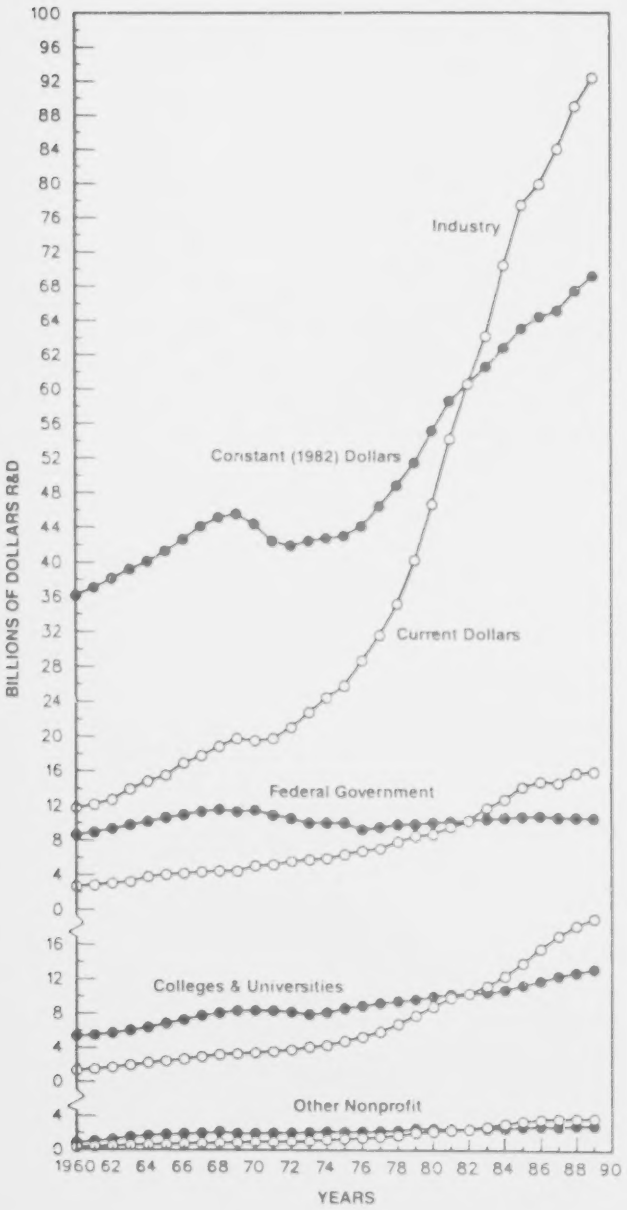

FIGURE 4. R&D EXPENDITURES BY SECTORS, 1960-89, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1982 = 100%)

A Look Toward 1990 and Beyond

While former issues of the Battelle Forecast and Analysis (through the 1983 edition) had been confined to considerations of the forthcoming year only, well-established commitments by both the federal government and industry generally have permitted a longer look at the R&D forecast. Judging from recent trends in government spending, long-term budget commitments (tempered by budget-cutting activities), and the existing overall business climate, it is estimated that 1990 sources for R&D will be:

Federal government	$ 61,580 million
Private industry	65,570 million
Colleges & universities	3,960 million
Other nonprofit organizations	1,890 million
TOTAL	$133,000 million

In addition, it is estimated that 1990 expenditures of R&D will be distributed among the four performing sectors as follows:

Federal government	$ 14,760 million
Private industry	95,770 million
Colleges & universities	18,780 million
Other nonprofit organizations	3,690 million

The overall 2.9 percent increase in funding and performance (expressed in constant 1988 dollars) will be unevenly spread among funding and performing sectors. It is expected that both funding and performance by the federal government will increase more slowly than average, while all other sectors' funding and performance will increase more rapidly.

The trends which pointed to a slowdown in the rate of growth, noted in the last two years' Forecasts, are expected to continue. While federal funding of R&D had increased substantially—largely influenced by defense programs—the growing federal deficit was beginning to take its toll. It was inevitable that new, and perhaps unpopular, actions would be required. To a significant degree, the Gramm-Rudman-Hollings Act has forced reductions in the rate of growth of expenditures. We expect that the rate of growth will continue to slow, although some real growth in federal spending will occur.

The picture regarding industrial R&D growth is a little more difficult to decipher, since other kinds of forces have an influence. Federal policies certainly affect industrial decision-making. Action or inaction relative to increased private and corporate taxes, limited import duties or other protectionist measures, R&D tax credits, patent policy, actions relative to mergers and acquisitions and cooperative research will continue to affect industrial commitment to R&D, as they have in the past. These generally act more as small perturbations on the more important driving forces for industrial support of research and development, namely, (1) the need to respond to competition (both foreign and domestic) and (2) the availability of funds from earlier years' sales and profits.

TABLE 6. CURRENT AND CONSTANT DOLLAR (1982 = 100) R&D EXPENDITURES IN THE U.S., 1960–1989, BY PERFORMERS

(All Amounts in Millions of Dollars)

	Total U.S.		Federal Government		Industry		Colleges and Universities		Other Nonprofits	
Year	Current	Constant	Current	Constant	Current	Constant	Current	Constant	Current	Constant
1960	13,523	47,389	1,726	7,496	10,509	34,168	1,006	4,926	282	799
1961	14,316	48,893	1,874	7,785	10,908	35,067	1,173	5,044	361	997
1962	15,394	50,762	2,098	8,181	11,464	36,078	1,374	5,281	458	1,221
1963	17,059	52,729	2,279	8,608	12,630	37,090	1,611	5,576	539	1,455
1964	18,854	54,533	2,838	8,989	13,512	37,989	1,904	5,911	600	1,644
1965	20,044	56,715	3,093	9,415	14,185	39,158	2,103	6,355	663	1,787
1966	21,846	58,859	3,220	9,750	15,548	40,462	2,345	6,778	733	1,868
1967	23,146	61,236	3,396	10,131	16,385	41,923	2,594	7,251	771	1,931
1968	24,605	62,938	3,494	10,375	17,429	42,923	2,868	7,557	814	2,084
1969	25,631	63,197	3,503	10,131	18,308	43,339	2,950	7,823	870	1,904
1970	26,134	62,235	4,079	10,284	18,067	42,215	3,072	7,833	916	1,904
1971	26,676	59,802	4,228	9,735	18,320	40,304	3,216	7,823	912	1,940
1972	28,477	58,765	4,590	9,354	19,552	39,787	3,383	7,665	952	1,958
1973	30,718	58,617	4,762	8,867	21,249	40,338	3,701	7,409	1,006	2,003
1974	32,864	59,243	4,911	8,882	22,887	40,653	3,888	7,616	1,178	2,093
1975	35,213	59,952	5,354	8,897	24,187	40,900	4,396	8,089	1,276	2,066
1976	39,018	60,576	5,769	8,120	26,997	41,990	4,876	8,355	1,376	2,111
1977	42,783	63,443	6,012	8,379	29,825	44,238	5,451	8,670	1,495	2,156
1978	48,129	66,394	6,811	8,699	33,304	46,553	6,342	8,897	1,672	2,245
1979	54,933	69,458	7,417	8,745	38,226	49,150	7,296	9,094	1,994	2,470
1980	62,594	73,581	7,632	8,928	44,505	52,735	8,307	9,448	2,150	2,470
1981	71,836	77,191	8,425	9,019	51,810	56,062	9,301	9,685	2,300	2,425
1982	79,364	79,364	9,141	9,141	57,995	57,995	9,803	9,803	2,425	2,425
1983	87,280	81,640	10,582	9,339	63,403	59,939	10,620	9,892	2,675	2,470
1984	97,793	84,249	11,572	9,461	71,470	62,086	11,741	10,187	3,010	2,515
1985	107,757	87,187	12,945	9,583	78,269	64,255	13,223	10,700	3,320	2,650
1986	112,495	89,181	13,535	9,644	80,629	65,615	14,826	11,182	3,505	2,739
1987	117,882	90,232	13,413	9,491	84,600	66,312	16,284	11,734	3,585	2,694
1988	124,915	92,959	14,500	9,461	89,400	68,560	17,400	12,118	3,615	2,820
1989	129,200	95,033	14,671	9,446	92,670	70,246	18,198	12,512	3,661	2,829

Source: Current dollar figures from Tables 1 and 2, deflated in terms of Battelle Cost of Research Index of Table 5.

Increases in university self-funding and performance in the near future continue to be, in part, a consequence of increased industrial actions of the recent past. The relaxation of apparent barriers to industrial cooperation created a funding mechanism which has infused substantial additional resources to the college and university sector. Counted as the sector's "own funds", this form of R&D support and performance will most likely continue to grow slightly over the next few years. However, it is also quite possible that a period of disenchantment will set in, particularly if any of three factors comes into play: (1) if the universities feel an encroachment upon their independence and sovereignty; (2) if supporting industries are unable or unwilling to reduce research to applications and profit; or (3) if sales and profit figures for industry are such as to reduce future "endowed investments" of this type. If any of these conditions comes to pass—and the next two to three years is the critical period—the industry/academia honeymoon may be merely an anomaly in the broader picture of long-term relations.

The total support of R&D involves an obvious "partnership" between government and industry in terms of both the levels of support and the division among basic research, applied research, and development. In addition, the development of technologies that have obvious applications in defense, space, health, and other federal concerns has significant implications in terms of industrial growth and competitiveness. Thus, continuing efforts have been made to promote greater cooperation between federal laboratories and the private sector. In many respects, this results from a lack of understanding

of the incentives of both the providers (federal laboratories) and the users (private industry).

The national commitment to continued support and growth of R&D is based upon the observation of the positive impacts of past actions. Each funding and performing sector—individually and in concert with the others—has made major contributions to the economic strength and security of the nation. Furthermore, this cooperative effort has permitted the assumption of a pre-eminent position among the nations of the world.

But as technological advances are made, a greater effort should be pursued to look at the long-term implications of R&D. There are many difficult questions that must be addressed, including considerations of the educational system, the potential displacement of skilled and unskilled laborers, the impacts of increased life expectancy, and the general changes in the delivery of goods and services. Government and business alike have a responsibility to take the longer view, to assess the impacts of technological change, and to develop alternative postures that can assure that the benefits of technological change can be realized without serious disruption to the society.

In all of the discussion which relates to both the short- and long-term projections for R&D, we should reiterate two major themes that have permeated this year's Battelle Forecast:

(1) Government actions relative to the budget and their long-term effects on R&D funding, and
(2) The industrial response to financial, not economic, concerns as reflected by the vagaries of the stock market, the predilection toward takeovers and mergers, and the return to more of the short-term, bottom-line rationale which governed earlier behavior.

Improvements in Information Resources

Industrial Line-of-Business R&D

Over the past several months, the theme of "competitiveness" continued its popularity. Along with "restructuring", "reindustrialization", and "infrastructure", this theme is likely to dominate discussions related to trade, economic growth, and any "new horizons" which will characterize the stand of the new administration. We do not expect the concept to be merely a popular buzzword, for it carries significance which was of concern long before the popularization of the word itself.

Earlier, we alluded to the difficulties associated with attempts to analyze industrial expenditures on R&D. The most readily available statistics—including those from the NSF surveys, the McGraw-Hill surveys, and the SEC 10-K forms—make no distinctions among R&D commitments to various lines of business. Chemicals research conducted by companies in the petroleum industry is not reflected in the statistics which refer to the broad industrial class of "Chemicals". Conversely, petroleum-related research conducted by the chemical companies is not included in figures which presumably represent "petroleum research". As automotive companies devote significant funds to electronics and computer research, as tobacco companies acquire food processing and distribution concerns, and as both inter- and intra-industry mergers or acquisitions occur, there is continued erosion of our understanding of the distribution of R&D and the factors which influence trends.

Industry R&D managers have long felt the need for more detailed information as it applies to their own commitments to R&D, the distribution of limited resources (both dollars and personnel), and the optimization of the R&D operation. The information needs include not just a compilation of their own efforts, but also a comparison between their own statistics and those which represent the industry as a whole. Without more detailed information regarding the trends among critical ratios in the various lines of business for which an R&D manager is responsible, the decision-making process is impaired.

As a result of this need, and recognizing the risks involved with individual attempts to gather data, Battelle has initiated projects which provide the type of analyses and comparative information that is an integral part of the resource management process. Starting with the petroleum industry, and expanding this to others, a procedure has been developed that addresses the basic information needs while avoiding the complications that would be faced by individual companies.

At the present stage of development, the approach provides line-of-business detail on relative expenditures and personnel levels devoted to R&D, technical services, and technician support; leading and lagging relations between R&D and sales, earnings and capital expenditures; and correlations between the R&D indicators and other measures of company activity, including materials or finished product throughput.

These are the types of data which assist individual companies in improving their own competitive position, in setting internal R&D policy, and in providing the input necessary to integrate R&D with the larger strategic planning and analysis process.

The expansion of the approach to other industries, including chemicals, automotive, paper and wood products,

ceramics, pharmaceuticals, information processing (including hardware, software, peripherals, etc.), composites, polymers, and the like, is expected to provide a better picture of the trends within R&D and a more nearly accurate accounting of the distribution of R&D effort. In addition, extension of the study to include both U.S. and foreign R&D efforts will give a truer picture of the competitive position of U.S. industry.

The basic nature of the program is such that the outputs of these surveys and analyses are generally proprietary, and information has thus far been provided only to the participating companies. To the extent that broad average values and trends can, by agreement with the participants, be made available, selected data will be included in future issues of the Battelle Forecast.

International Comparability

While intra-industry comparability is useful for assisting individual companies to analyze their competitive position and develop R&D strategies to meet future markets, international comparability is often sought as a means of determining whether total U.S. efforts will result in maintaining a preferred position relative to future trade and economic strength. Broad statistics on total R&D, selected comparisons on R&D in various functional areas, and estimates of R&D as a ratio to GNP or equivalent are usually available through the National Science Foundation, the Organization for Economic Cooperation and Development (OECD), and other agencies.

The numbers that describe total U.S. and foreign R&D efforts are instructive to the extent that they permit general assessment of the relative commitment to R&D and some insights into the distribution of total R&D resources among various functional areas. However, these types of data are of relatively little value when attempting to formulate policies or approaches that must be translated into specific actions. The total value of R&D investment provides no more detail on the national scale than does the total value of R&D as reflected in the industrial R&D quoted in the sources cited in the previous section. That is, total values tell you everything, while telling you nothing. They provide gross statements relative to national expenditures, but they say nothing about the structure of the R&D effort, the relationships among supporting and performing sectors, and the manner in which these relationships change as a result of policy actions.

In its simplest structure, the U.S. data, as presented by NSF and Battelle, consider the four major source/performer sectors of federal government, industry, colleges and universities, and other nonprofit organizations. Support for the Federally Funded Research and Development Centers (FFRDCs) is usually separated only for those FFRDCs managed by colleges and universities, while that for FFRDCs managed by industry or nonprofit organizations is generally absorbed into the total values which represent these sectors. Furthermore, as has been noted earlier, the R&D support provided by subnational units of government (such as direct support to the state universities) or through endowments or other gifts to R&D-performing institutions is not isolated, but is absorbed under the category of "own funds".

Although the situation is not perfect elsewhere, Battelle's preliminary analyses have shown that other countries' statistical efforts are more disaggregated. They permit inspection of more detailed relationships between the various classes of supporters and performers of R&D, and—taken to the most logical conclusion—they provide the background tools that are necessary for sensible policy development and evaluation. For example, nowhere in the U.S. collection of R&D statistics is there a continuing measure of the interactions between industry (as a supporter of R&D) and the federal laboratories (as a performer); the industry/federal cell of Table 2 is *defined* as being empty, while it is known that a nonzero entry should be made. Thus, there is no well-defined measure of the extent to which the Stevenson-Wydler Act and the subsequent Technology Transfer Acts of various years have been effective in promoting this interaction.

Furthermore, there is no isolation of the contributions made by state governments to the general conduct of R&D in the state universities, or the specific R&D projects done on behalf of state government. And as a final example, there is no continuing data base that provides insights into the distribution of industrially-supported R&D into cooperative programs or the separation between industry-funded work that is carried out in an industry's own laboratories as compared with that carried out in other industries' facilities.

While not all of the detail available in other countries' data may be necessary for the U.S. setting, it is obvious that the U.S. statistics provide only limited value relative to policy development. As the issue of competitiveness continues to be raised in political rhetoric, industrial policy, and trade discussions, and as concern for long-term economic strength transcends mere political expediency, efforts should be directed toward improved understanding of the relative position of the U.S. R&D enterprise and toward assuring that the policy debate takes place in an environment of knowledge. Furthermore, efforts should be made to learn the lessons of history as they apply to the future.

TECHNICAL APPENDIX

NSF DEFINITIONS OF RESEARCH AND DEVELOPMENT

Many activities, from one viewpoint or another, may be termed "Research and Development". The National Science Foundation (NSF) has, since its inception, been concerned with both the definition and the measurement of R&D. We probably can do no better than again quote the most recent definitions that the NSF has evolved. By these definitions, we can say:

"*Research and development* . . . consist of basic and applied research in the sciences (including medical sciences) and in engineering and activities in development . . .

"*Research*, which encompasses both basic and applied, is systematic, intensive study directed toward fuller scientific knowledge of the subject studied.

"*Basic research*. For three of the sectors—federal government, universities and colleges, and other nonprofit institutions—the definition of basic research stresses that it is directed toward increases of knowledge in science with . . . a fuller knowledge of understanding of the subject under study, rather than a practical application thereof. To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to indicate that basic research projects represent . . . original investigations for the advancement of scientific knowledge . . . which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

"*Applied Research*. The following is the core definition in the NSF questionnaire sent to the universities and colleges: '*Applied research* is directed toward practical application of knowledge'. Here again, the definition for the industry survey takes account of the characteristics of industrial organizations: it covers '. . . research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes'. By this definition, applied research in industry differs from basic research chiefly in terms of objectives of the reporting company.

"*Development*. The NSF survey concept of development may be summarized as '. . . the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes'."*

* National Science Foundation. *National Patterns of R&D Resources, 1953-78/79*. NSF 78-313, p. 25.

Corporate headquarters are located in Columbus, Ohio

Putting technology to work is at the heart of Battelle's worldwide activities. Battelle's staff—with its broad range of scientific, technical, and management backgrounds—assists both industry and government in developing, commercializing, and managing technology.

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